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Presented to:

AIAA Missile Science Conference

Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities



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20 November 2008

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 01 NOV 2008		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Aviation and Missile Research, Development and Engineering Center, Redstone Arsenal, Alabama, 35898				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADM202644. AIAA Missile Sciences Conference Held in Monterey, California on November 18-20, 2008, The original document contains color images.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 21	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Geographically Distributed Stimulation Architecture For Missile Defense System HWIL Weapon Facilities

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- **Distributed Single Stimulation Framework (DSSF) Objectives**
- **Notional Scenarios to be represented**
- **DSSF Design and Truth Data Flow**
- **Software Architecture**
- **Hardware Architecture**
- **Summary**

Why a Single Stimulation Framework

- The goal of a Geographically Distributed HWIL event is usually system-level interoperability and performance evaluation
- System-level evaluation requires centralized control and commonality of inputs to ensure all participating elements are acting upon the same information
- Inconsistent representation of physics can inject test-induced errors into the performance of the system
- If Element “A” processes threat system “X” one way, and Element “B” processes it another and both send data to Element “C”, artificial errors may be injected into the test that lead to false performance results

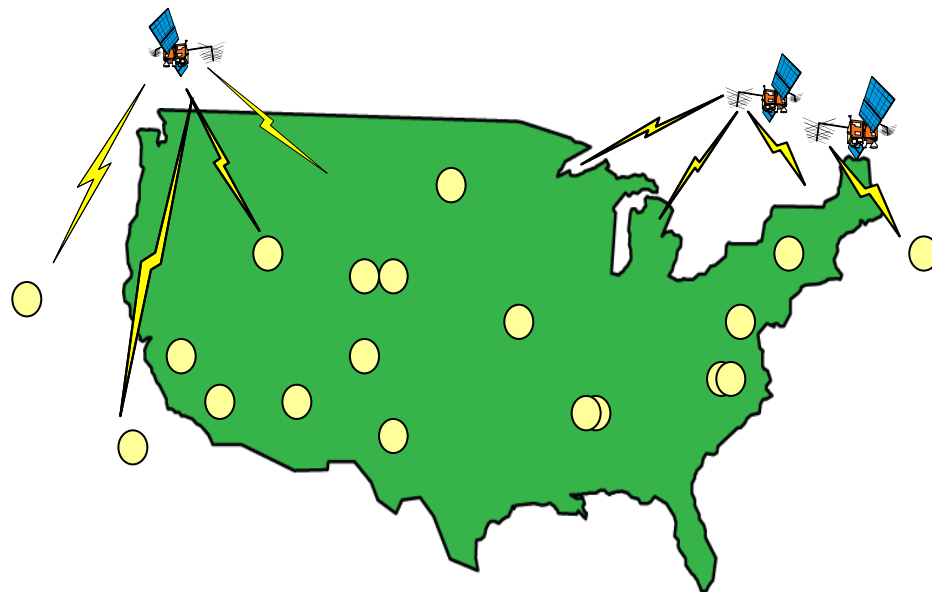
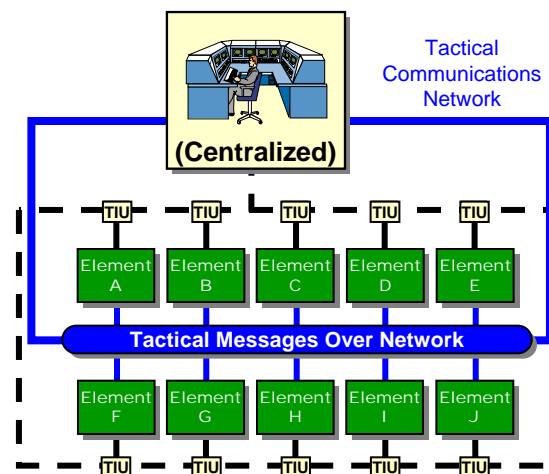


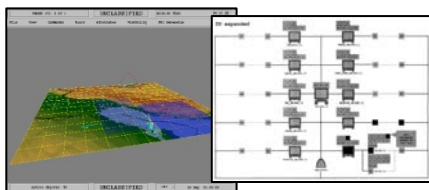
Figure: Example of Distributed Locations used in a Ground Test Architecture



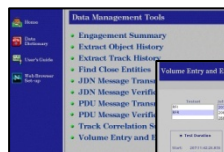
Distributed Single Stimulation Framework is...



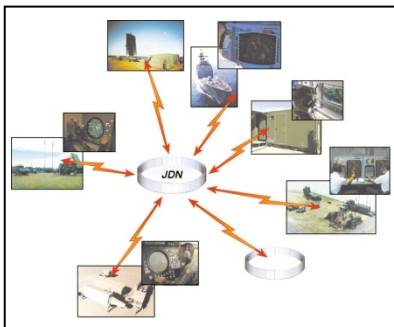
Coordinated Planning and Control



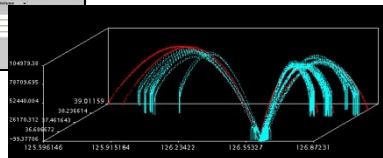
Monitor Event with Truth and Perceived Activity



Post-Event Data Collection and Assessment



Distributed Real-Time HWIL Connectivity



...Verified, Validated, and Accredited Hardware-in-the-Loop (HWIL) Stimulation Tool

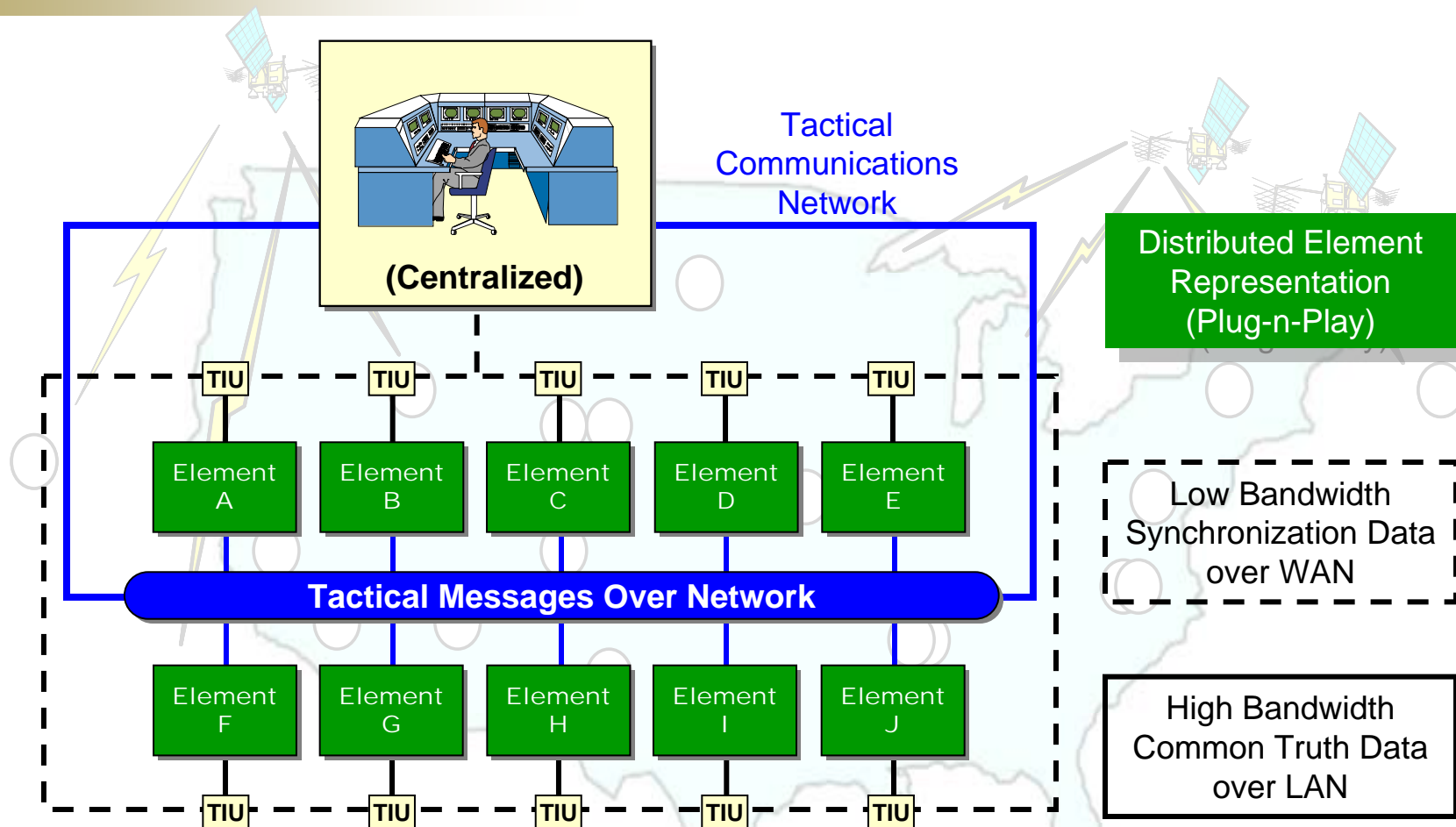
... Uses Approved Threats to Stimulate Tactical HW & SW Elements

... Link the Elements that Produce the Operational Messages

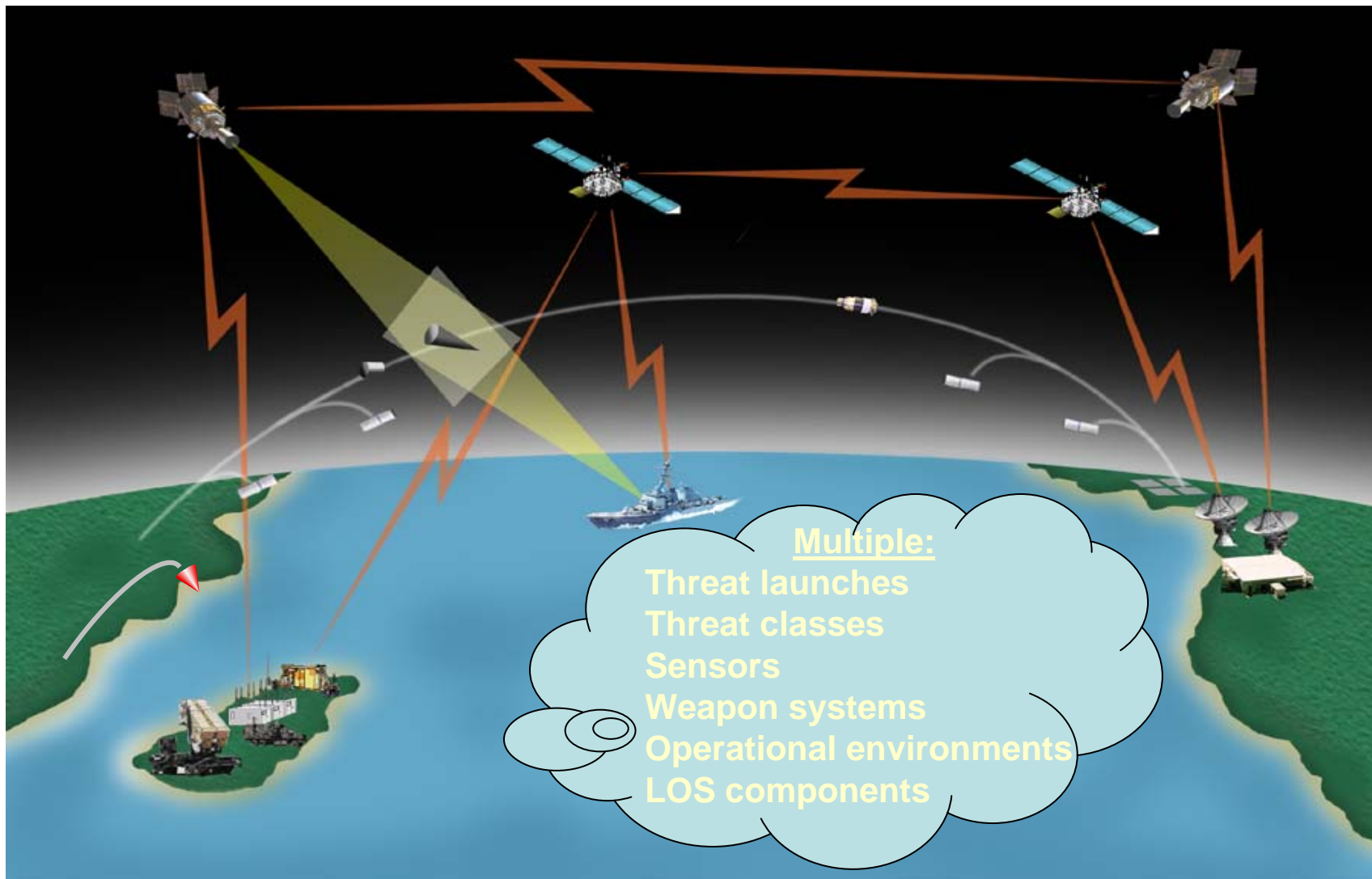
... Provide Characterization and Assessment of Units Under Test

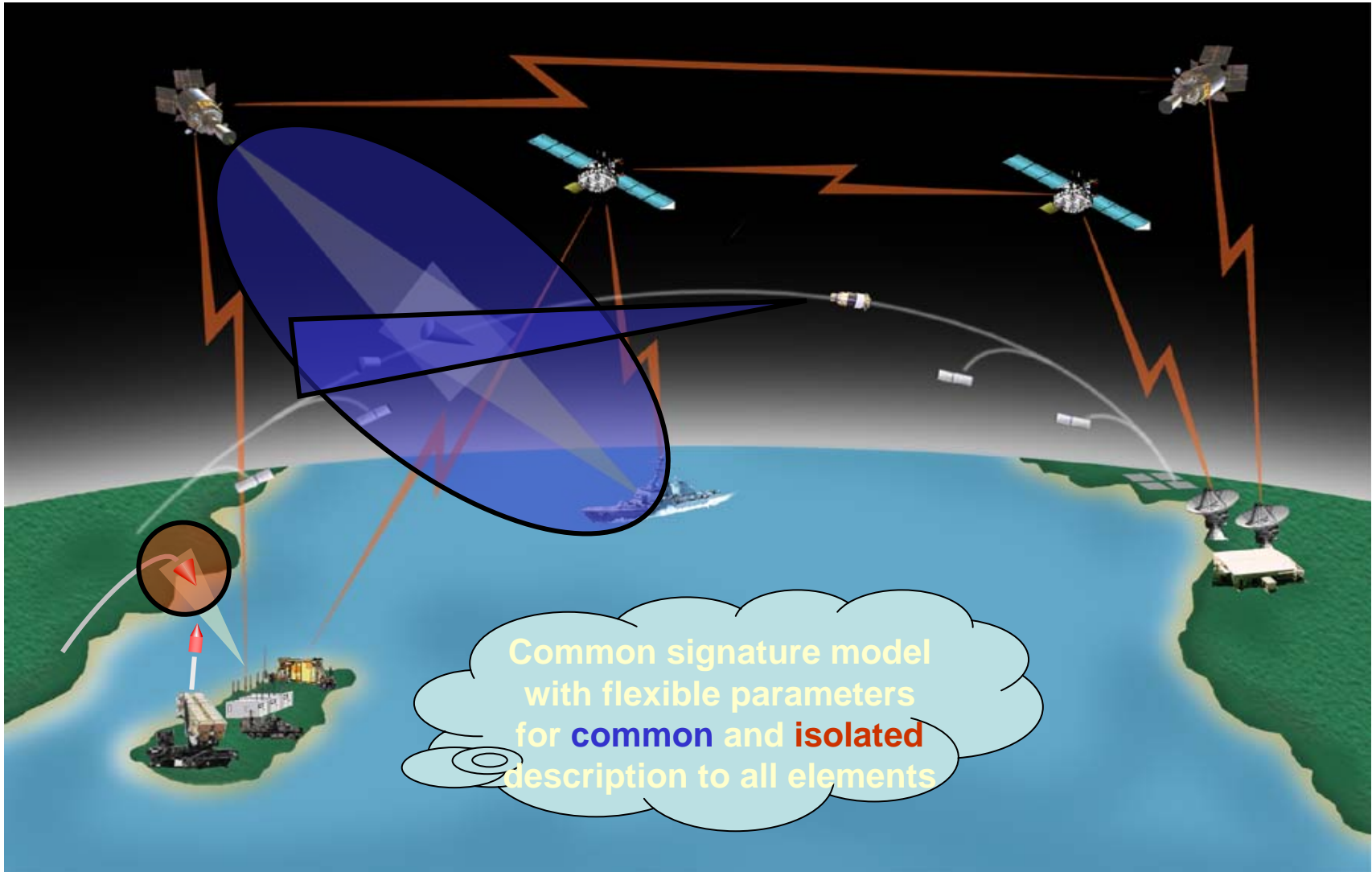
Real-Time, Dynamic, Interactive, Centrally Controlled, Geographically Distributed, GPS Synchronized System

Stimulation Framework Integrated Architecture Summary



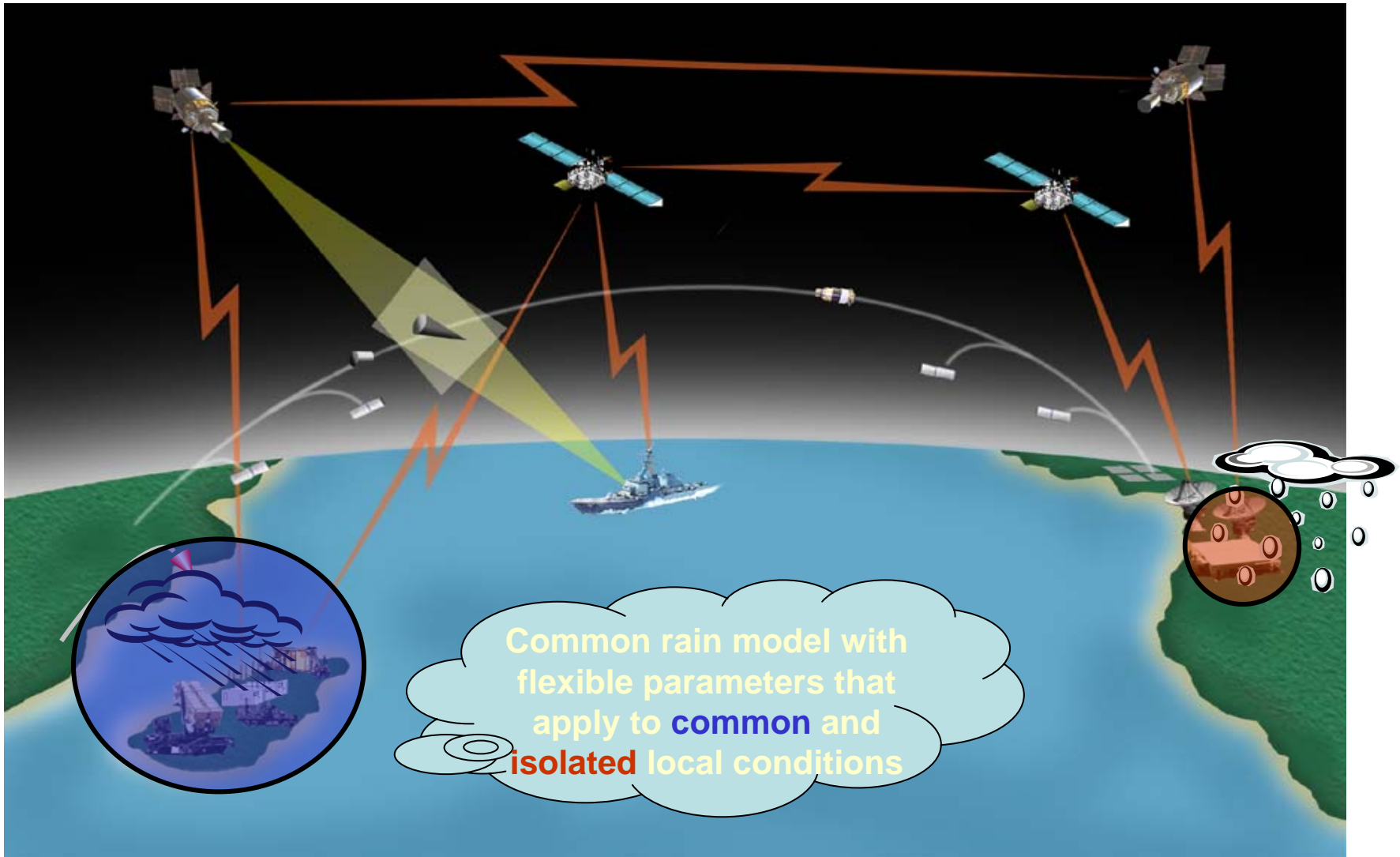
The Single Stimulation Framework Provides Centralized Control of Geographically Distributed System Components With Message Traffic Designed to Accommodate Network Capabilities and Allows for Easy System Reconfiguration to Test System Interoperability and Performance





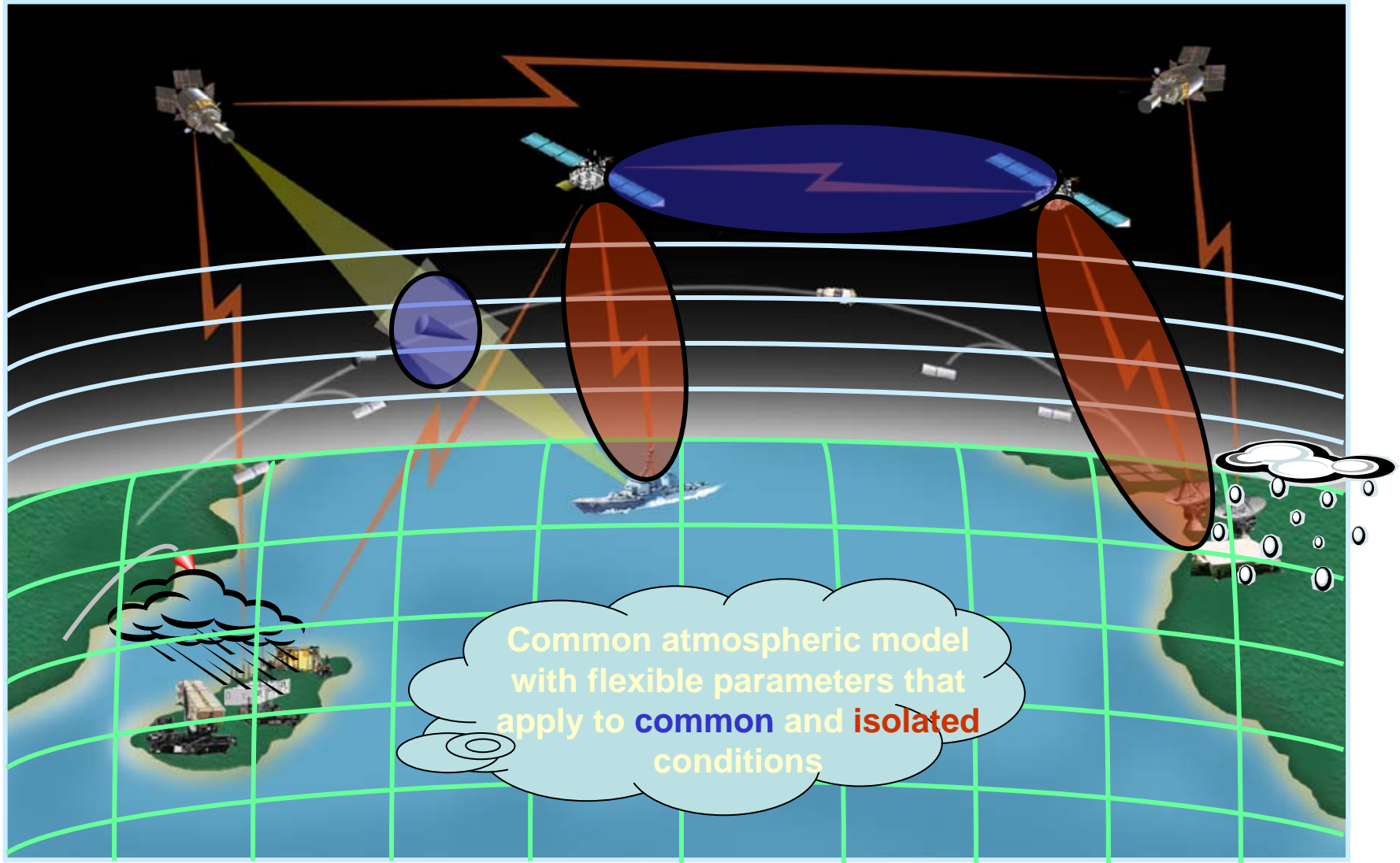
Environments in HWIL

-Rain-

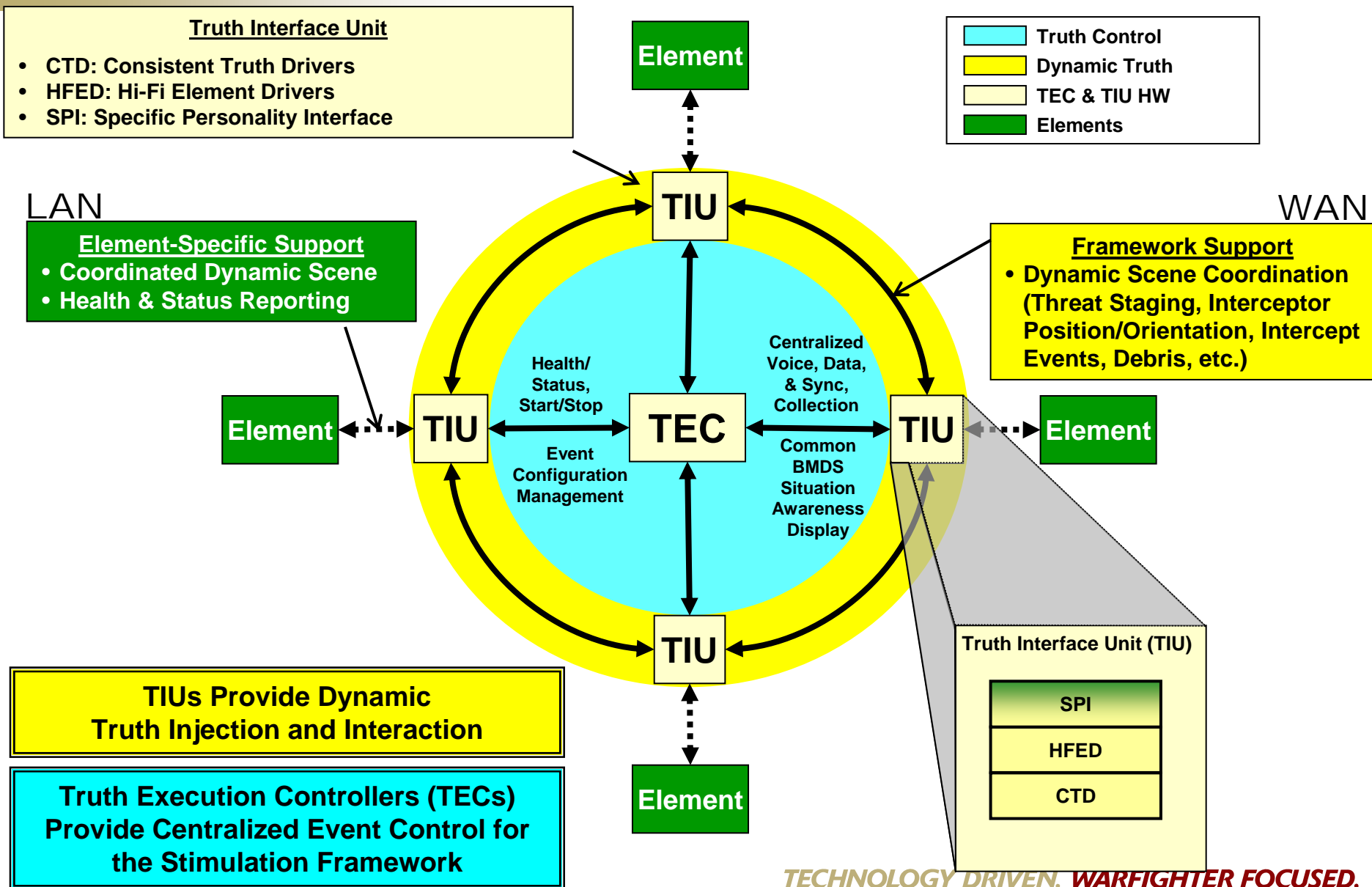


Environments in HWIL

-Atmospheric Model-

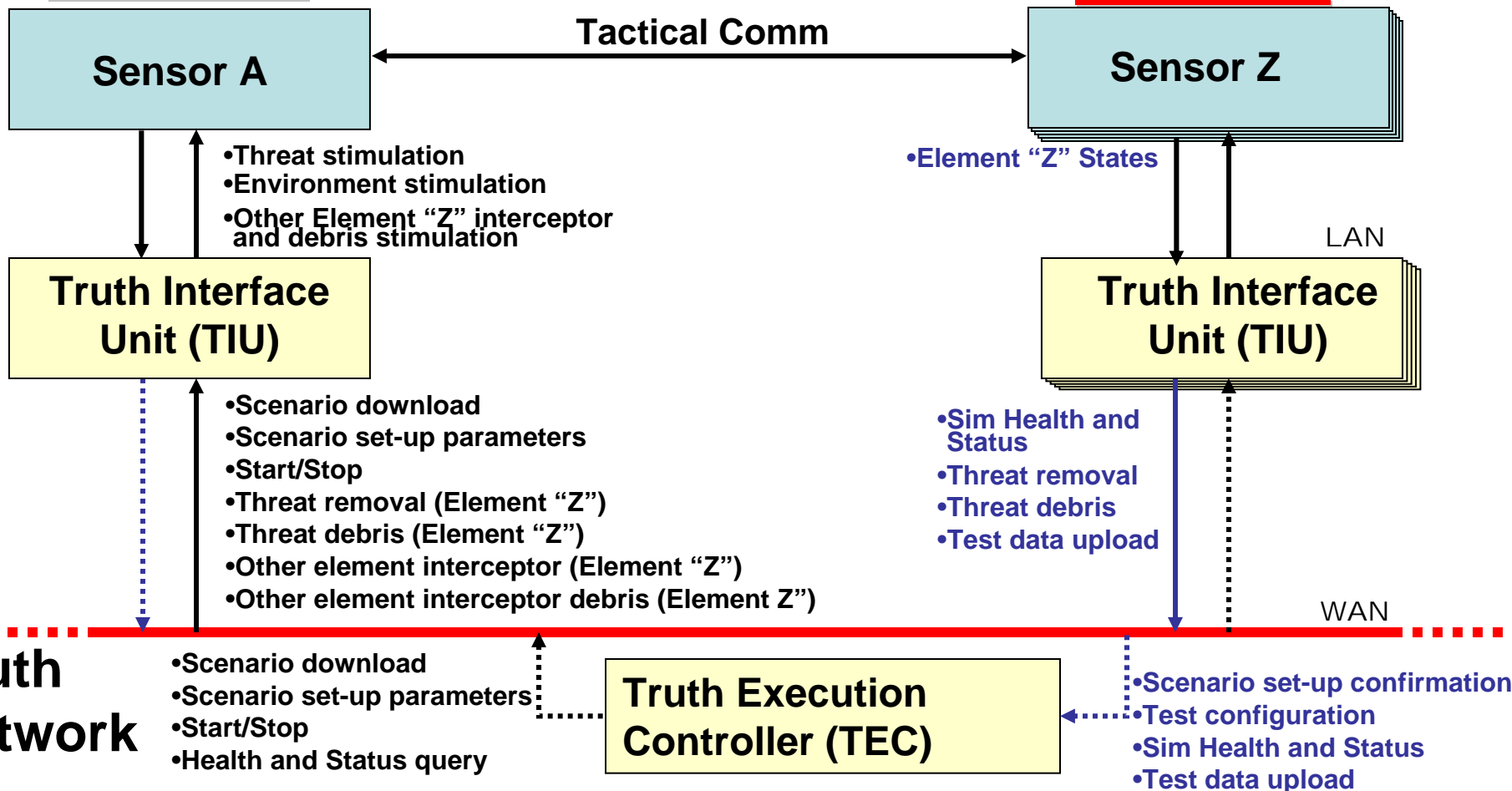


Multi-Element Stimulation Framework Design



Element A

Element Z

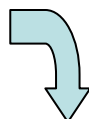


All truth data exchanges are defined in the Interface Control Document (ICD)

- Truth Network Data
 - Scenario download from TEC to TIU
 - Event Test Start/Stop
 - Event Test Health and Status
 - Interceptor position, velocity, and acceleration truth data from Element A to TEC and Elements Z
 - Interceptor debris truth data from Element A to TEC and Elements Z
 - Threat detonation/removal from Element A to TEC and Elements Z
 - Threat debris truth data from Element A to TEC and Elements Z
 - *No tactical communication messages/data from Element sensor or Element Battle Managers*
- Operational Network Data
 - Sensor track data from Element A to Elements Z
 - Battle Manager control and response messages
 - Tactical action reporting
 - Operational Health and Status
 - *No truth stimulation or event control data*

Pre-Mission

- Define Test Cases for event
- Parse trajectories
- Blue force laydown
- Radar Cross Section and Electro Optical data
- Other Test Configuration parameters
- Test Case download to TIUs



Mission

- Establish test control voice
- TEC starts Health & Status reporting cycles
- TEC exchanges initiation parameters with elements
- TEC issues Start
- Event Test start
- TIUs begin threat state injection to elements
- TIUs distribute "own-ship" state vectors from elements
- TIUs distribute interceptor state vectors
- TIUs propagate engagement debris for kills
- TEC displays H&S, truth and tactical msg track data
- TEC requests test integrity metrics
- TEC issues Stop



Post-Mission

- Data file upload from all elements
- Parse data into Oracle database
- Data file status report
- Quick-Look report
- Database queries, plots
- Analytical tools
- Data file download

**Software is government-owned,
developed, and non-proprietary**

Input

Trajectory Data

- Time zero based trajectories, flight paths
- Multiple Threat formats and Update rates
- Earth Centered Inertial (ECI) or Earth Centered Rotating (ECR)
- Gravity terms up to 18x18 per request
- 3 DOF and 6 DOF capable

Scatter Point RCS Data

Test Case Description Document

- Launch Times
- Blue Force lay down

ICD Parameters

- Entity Type enumerations
- Element identifiers
- IP addresses, port numbers

Processes

Pre-Mission Data Parsers

- Convert ECI to ECR, Euler angles to Quaternions
- Insert state vectors into threat library database
- Dead Reckoning flags state vectors required to maintain one meter position accuracy
- Install RCS/EO data in database



Test Case Builder

- Assemble trajectories from threat library and offset to prescribed launch times
- Blue force laydown
- Connectivity parameters
- Environmental parameters
- IFF scripts
- Pk=0/1 scripts



Test Case Download

- Creates Test Configuration "flat files"
- Creates threat scenario preview report
- Creates 17 column format



Install Test Configuration Data on TIUs

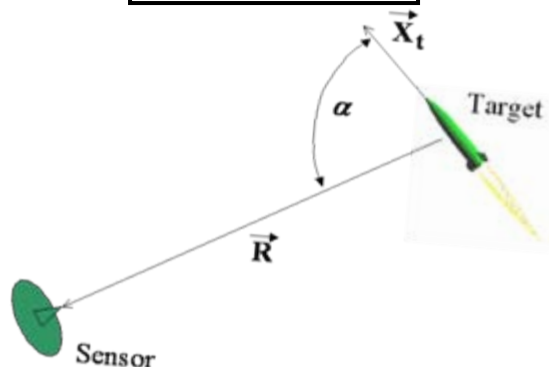
Test Case Injection

Mission (TEC) and Truth Interface Unit (TIU)

Threat presented to Element Driver (ED) via DIS PDU

DIS PDU provides:
State Time; XYZ
Position; XYZ
Acceleration; XYZ
Velocity; XYZ
Orientation

Test run PDUs presented are Recorded at each TIU



Data available to Post-mission Tools

PDU Data (truth) uploaded to Stimulation Database

Interceptor PDU Data from other Stimulation elements is exchanged within framework dynamically as it occurs (launch, position, kill, detonation, altitude, weather, merge blue force)

PDU Data Verification: State Count, maintain positional accuracies, thinning of some truth information due to Element bandwidth

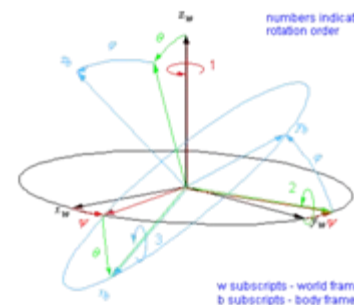


Figure 1-1. Definition of Yaw-Pitch-Roll Euler Angles

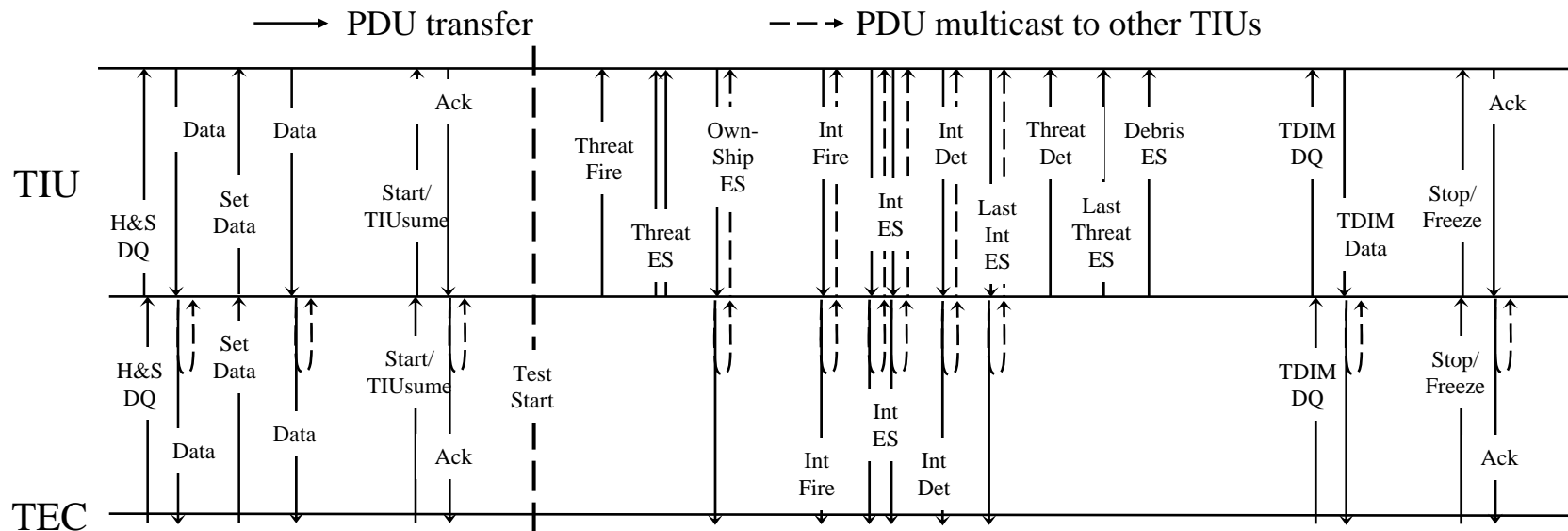
\mathbf{p} extrapolated position vector in world coordinates
 \mathbf{p}_0 position vector in world coordinates at the initial time
 \mathbf{v}_0 velocity vector in world coordinates at the initial time
 \mathbf{a} acceleration vector
 Δt time increment for the dead reckoning step
 $[\mathbf{R}]_{w \rightarrow b}$ entity's extrapolated world to body orientation matrix
 $[\mathbf{DR}]$ dead reckoning matrix
 $[\mathbf{R}_0]_{w \rightarrow b}$ the entity's initial world to body orientation matrix

$$\mathbf{p} = \mathbf{p}_0 + \mathbf{v}_0 \Delta t + \frac{1}{2} \mathbf{a} \Delta t^2$$

$$[\mathbf{R}]_{w \rightarrow b} = [\mathbf{DR}] [\mathbf{R}_0]_{w \rightarrow b}$$

Notional Mission Functional Overview (Cont.)

PDU Message Sequence for TEC and TIUs



↑ TEC begins H&S 10 sec cycles after voice coordination

↑ TEC issues Set Data PDUs to confirm position/heading, weather, satellite background, movement

↑ TEC issues Start/Resume PDU to announce time of start and Sim time

↑ Test starts at time indicated in Start/Resume PDU

↑ TIUs begin issuing Fire PDUs for scripted munitions

↑ TIUs begin issuing Entity State PDUs for scripted objects

↑ EDs begin issuing Entity State PDUs for "own-ship positions"

↑ ED issues Fire PDU for interceptor launch

↑ ED issues ES PDUs for interceptor flight

↑ ED issues Det PDU for interceptor kill (or miss)

↑ ED issues ES PDU to remove interceptor

↑ TIU issues Det PDU for threat

↑ TIU issues ES PDU to remove threat

↑ TIU issues ES PDUs for threat debris

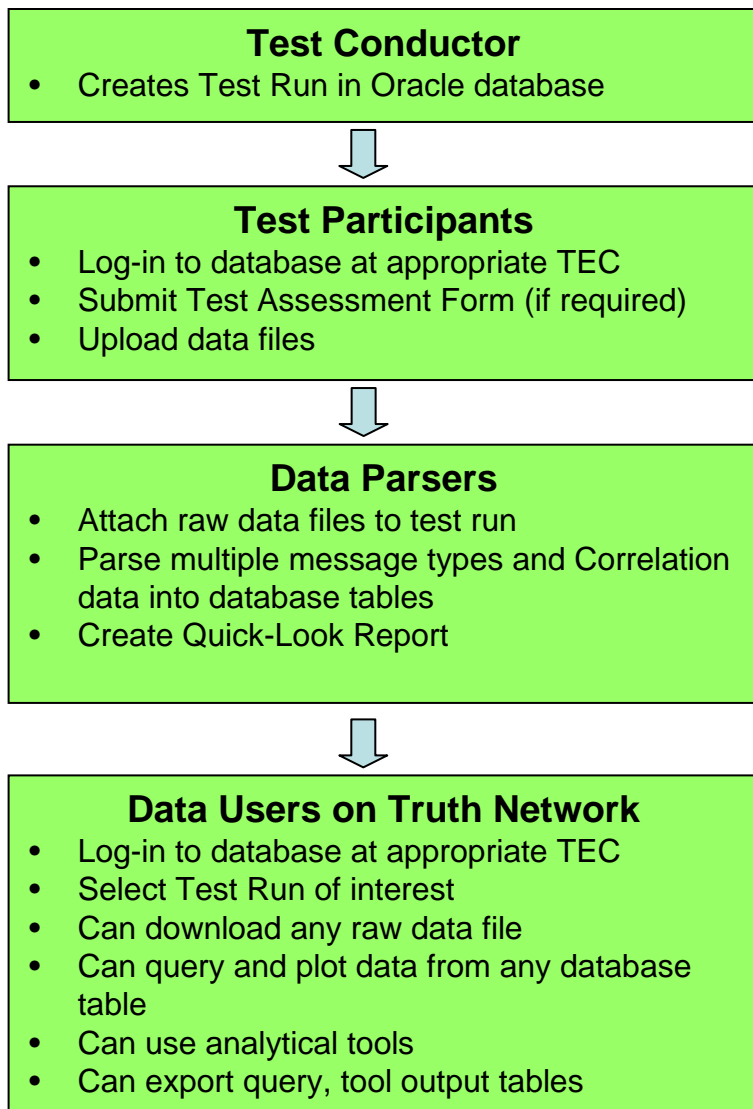
↑ TEC issues TDIM request

↑ Test stop

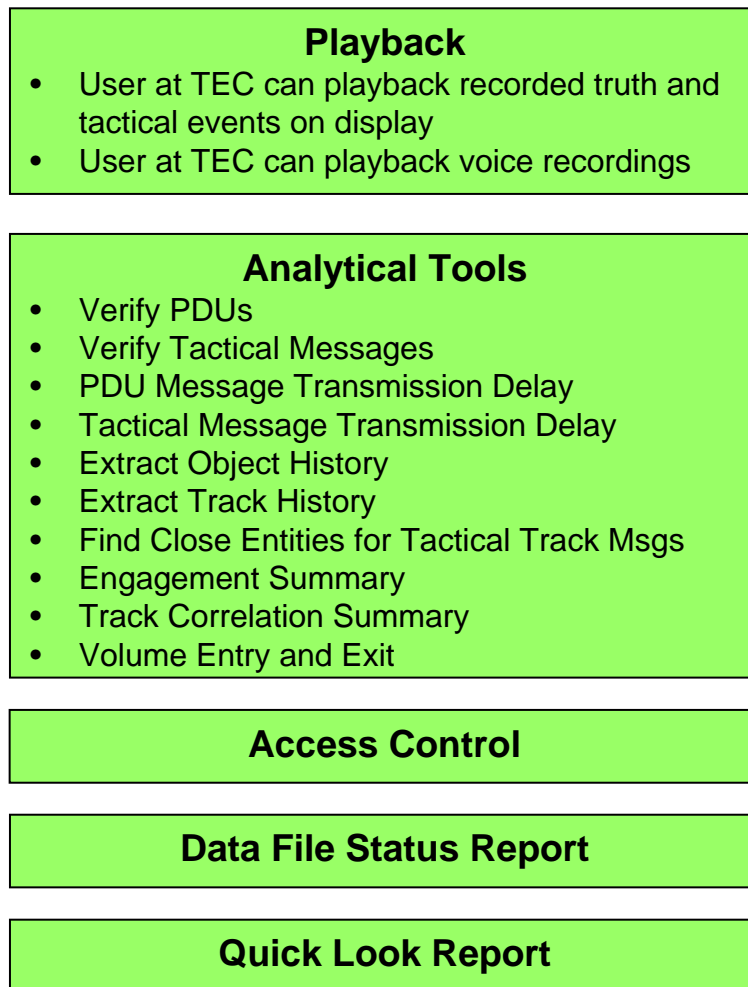
Major Mission SW Functions

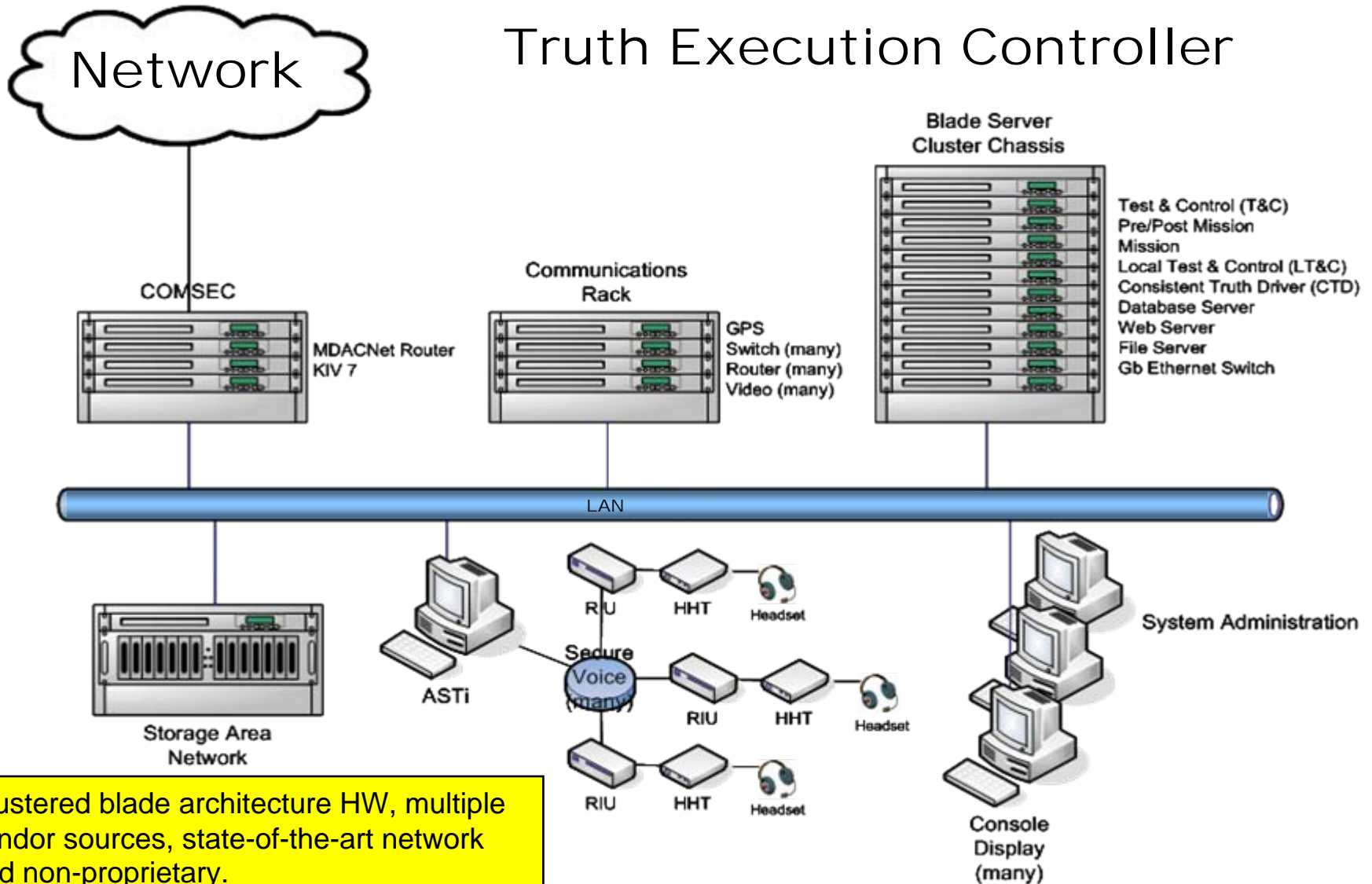
- TEC and TIU use same SW
- TEC provides operator test and control
- TIUs can operate in stand-alone with Element
- TIUs convert trajectory files to ES PDU stream
- TIUs forward PDUs received from Element
- TIUs propagate engagement debris for kills
- TEC displays H&S, truth and tactical msg track data
- Data collection

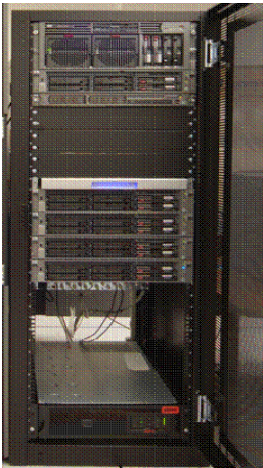
Data Flow



Post-Mission Features







Truth Interface Unit – Rack (TIU-R)

- Highest Storage Capacity
- Processor Scalable
- Full Environment Stimulation capability
- TEC-Capable
- Transportable
- \$\$\$



Truth Interface Unit – Portable (TIU-P)

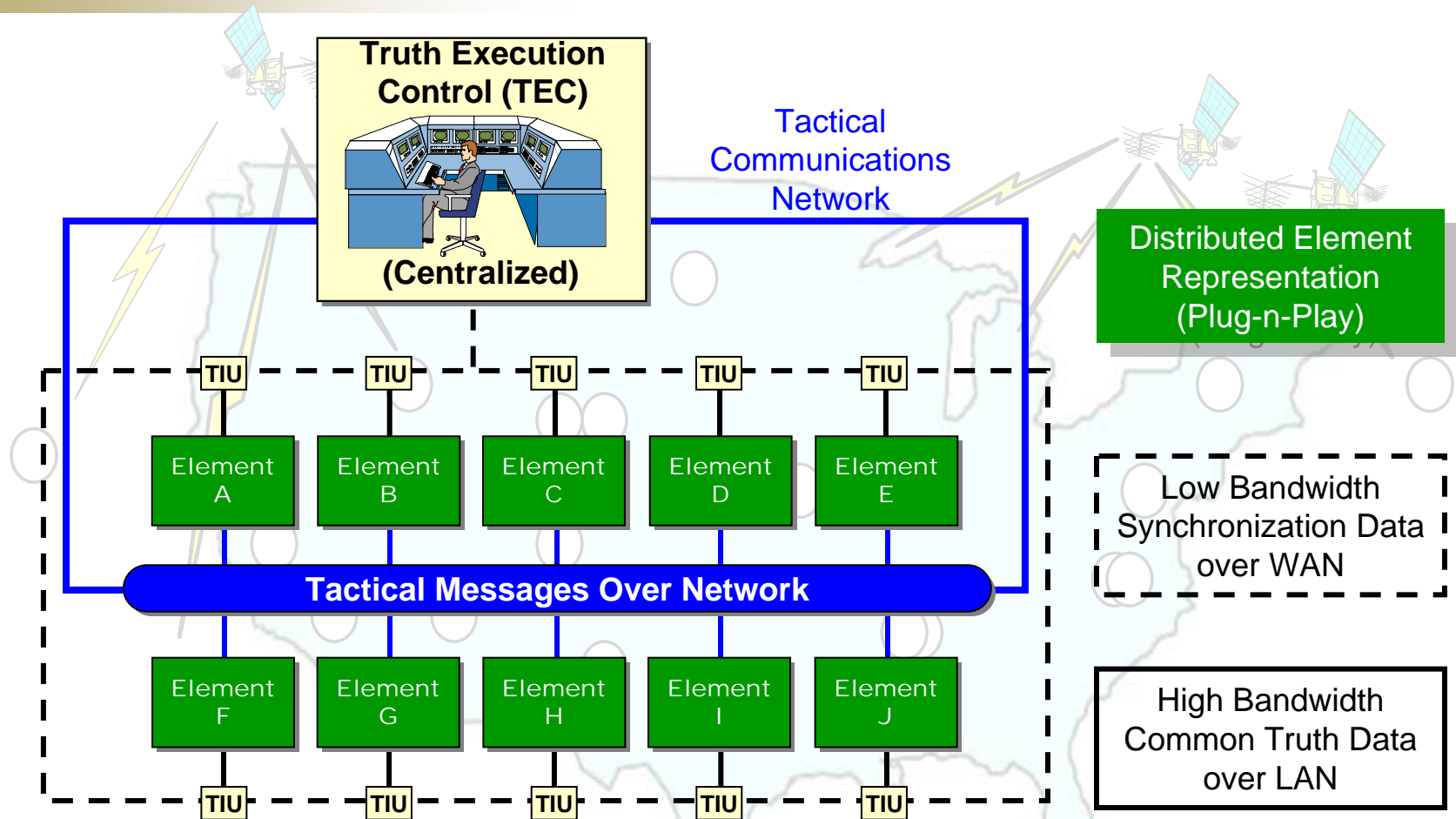
- Smaller Storage Capacity than TIU-R
- Dual or Quad-Core Processors capable
- Limited Environment Stimulation capability
- TEC-Capable
- Ruggedized/Reinforced, Mobile
- \$\$



Truth Interface Unit – Laptop (TIU-L)

- Smaller Storage Capacity than TIU-R
- Dual or Quad-Core Processors capable
- Limited Environment Stimulation capability
- TEC-Capable
- Commercial Laptop, Mobile
- \$

Stimulation Framework Integrated Architecture Summary



The Single Stimulation Framework Provides Centralized Control of Geographically Distributed System Components With Message Traffic Designed to Accommodate Network Capabilities and Allows for Easy System Reconfiguration to Test System Interoperability and Performance